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Lysine-Energy Relationships in Corn-Soybean Meal Diets for Growing and Finishing Swine

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LYSINE-ENERGY RELATIONSHIPS IN CORN-SOYBEAN MEAL DIETS FOR GROWING AND FINISHING SWINE

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FOR GROWING AND FINISHING SWINE

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

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INTRODUCTION

Increasing feed costs in recent years have led researchers and producers to look to different sources for their feedstuffs. Many by-products of various industries have been studied to determine their potential as livestock feeds. One product that has been used extensively in poultry feeds is waste fat from the packing industry. Fat offers a concentrated source of energy that can be used to spare feed grains in the diet by increasing the total dietary energy and increasing feed efficiency.

The amino acid lysine represents another opportunity to decrease feed costs of swine diets when protein supplementation is costly. Lysine is the first limiting amino acid in most practical swine diets. The addition of lysine has proven effective in diets adequate in other nutrients but deficient in lysine.

The purpose of the research conducted and summarized here was to study the effect of different levels of fat and lysine in diets adequate in other nutrients. Most studies indicate that increasing energy causes a decrease in feed consumption which increases the need for additional protein to meet total protein requirements. This study was designed to determine if a similar relationship exists for lysine and energy. Rate of gain, feed consumption, feed efficiency and blood urea nitrogen levels were the criteria evaluated for growing and finishing swine.

REVIEW OF LITERATURE

Limiting Amino Acids in Corn and Corn-Soy Diets

Corn is low in several essential amino acids for growing and finishing swine. The addition of lysine by Baker et al. (1969) to fortified corn diets of 8.8% protein for growing pigs (21 to 24 kg) resulted in decreased feed consumption and rate of gain. The further addition of tryptophan to the corn diet supplemented with lysine overcame the growth depression and increased feed consumption. Amino acid supplementation of all-corn diets for finishing swine (61 kg) was studied by Gallo and Pond (1968). A response to lysine was obtained only when tryptophan was also added to the diet. The above results would suggest that all-corn diets are first limiting in tryptophan and second limiting in lysine for both growing and finishing swine. Baker et al. (1969) found no advantage to adding DL-methionine to an all-corn diet for growing pigs.

Corn-soybean meal mixtures are generally formulated to meet the pigs' requirements for total protein and to meet amino acid requirements. The National Research Council (N.R.C., 1973) specified that a 16% crude protein diet is necessary for the growing pig and a 13% protein diet is needed to meet the protein requirements of the finishing pig. If the protein level for the growing pig is dropped to 12% by altering the ratio of corn and soybean meal, lysine is calculated to be the first limiting and methionine the second limiting amino acids, with tryptophan and threonine being met at 100% of the requirement as outlined by the N.R.C. (1973).

In experiments to further evaluate the limiting amino acids in corn-soybean meal diets, Mahan et al. (1973) fed low protein diets to 20-kg growing pigs. A 12% diet was fed unsupplemented, supplemented with L-lysine and with lysine and either tryptophan, methionine or threonine. A 16% corn-soy diet was fed as a positive control. The addition of lysine to the 12% protein diet resulted in increased gain, feed intake, nitrogen retention and feed efficiency. Lysine plus tryptophan further increased growth and nitrogen retention and improved feed response. Results were similar to those for pigs fed the 16% control diet. No significant differences were observed with either added methionine or threonine.

The addition of L-lysine to 12% protein, corn-soybean meal diets fed to young pigs was also shown to significantly increase rate of gain and improve feed efficiency (Noland et al., 1959). Further evaluation of protein and amino acid levels was conducted by Sharda et al. (1976). Diets of 12, 14 and 16% protein were fed to growing pigs. The addition of lysine to the 14% diet resulted in pig performance similar to that achieved on the 16% protein diet. Lysine and tryptophan additions to the 12% protein diet also resulted in pig performance equal to that of pigs fed the 16% protein diet. Methionine or threonine additions to the diet decreased pig performance. Acker et al. (1959) obtained similar results when lysine was added in .05% increments from 0 to .15% in 12% protein, corn-soy diets. Additions of lysine up to .1% caused an increase in rate of gain and feed efficiency. The addition of .15% lysine caused a decrease in feed efficiency and rate of gain compared to the diet supplemented with .1% lysine. Methionine additions had no significsnt effect on rate or efficiency of gain.

In contrast to the above results, Meade et al. (1966) added lysine and/or methionine to 12 and 14% protein diets for 25-kg growing pigs. The supplemented diets were compared to 12, 14 and 16% protein diets. Supplementation with these amino acids either singly or in combination resulted in no improvement in either growth rate or feed efficiency.

In work with finishing swine, Wahlstrom and Libal (1974) reported that lysine additions to an 11% protein, corn-soybean meal diet supported more efficient growth than the unsupplemented diet or the diet with added methionine. Sharda et al. (1976) observed an increase in rate and efficiency of gain when feeding 10% protein, corn-soybean meal diets with the addition of supplemental lysine for finishing swine. The results were equivalent in performance to those obtained on a 13% protein, corn-soy diet. In another trial, protein was decreased to slightly below the 10% protein used above. The addition of both lysine and tryptophan was needed to increase performance to that achieved on a 13% protein, corn-soy positive control. As in previous work, DL-methionine additions had no effect on performance.

<u>Lysine Requirements</u>

Mertz *et al*. (1949) first demonstrated that lysine was a necessary amino acid for the growth and development of the weanling pig. Brinegar *et al*. (1950) further reported that as the protein level of the diet increased for weanling pigs so did the requirement for lysine. Gupta *et al*. (1958) found that increasing protein increases the requirement for lysine, although actual lysine availability in the feed was not decreased. In studies with rats, the minimum lysine requirement increased from .54 to .67 to .84%, as the dietary protein was increased from 8 to 12 to 16%, respectively. Increases in protein content above 16% did not significantly affect lysine requirement (Bressani and Mertz, 1958).

Cahilly *et al*. (1963) found that pigs fed the 16% protein diets containing .3, .6, .9 and 1.2% lysine from 13.6 to 81.8 kg gained more slowly on diets containing .3% lysine. The largest difference in performance came in feed efficiency, as feed required per pound of gain was 5.59, 4.12, 3.64 and 3.42 at lysine levels of .3, .6, .9 and 1.2%, respectively. Further, blood studies indicated that the pigs receiving the lysine deficient diets had lowered hemoglobin and hematocrit levels. In studies utilizing only growing pigs, Bowland (1962) reported that pigs grown from 13.6 to 50.0 kg gained equally as fast when fed 13% protein, corn-soybean meal diets, supplemented with L-lysine to equal the amount in a 16% protein, corn-soybean meal diet, as did animals fed the 16% diet. Meade and Teter (1956) observed that, when lysine was added to a 12% protein diet for growing swine, nitrogen utilization was decreased possibly because of a lysine imbalance. Lysine additions to 14 and 16% protein, corn-soybean meal diets caused no significant increases in nitrogen retention. Sharda et al. (1976) reported similar results in 20-kg pigs. The addition of lysine to 12% protein diets did not equal gains of pigs fed the 16% diets until tryptophan was also added.

In finishing swine diets, Aldinger and Roberts (1973) studied the effect of lysine additions to 11 and 13% protein diets and its influence on rate of gain and feed efficiency. The results indicated that the lysine requirement may be higher for maximizing feed efficiency than for rate of gain. The addition of .1% lysine to the 11% protein, corn-soy diet increased daily gains (1.79 vs 1.94) and decreased feed required per pound of gain (3.43 vs 3.22). Adding .1% L-lysine to the 13% protein diet did not increase gain but did decrease the feed/gain from 3.29 to 3.11. In similar work, Brown et al. (1973) reported finishing swine fed a 13.3% protein diet with varying levels of lysine, .35, .45, .55, .65 and .75%, required .62% lysine for maximum feed efficiency and .48% for maximum daily gain. Jurgens et al. (1973) reported increased daily gains and feed efficiency by increasing lysine from .41 to .49%. An increase from .68 to .74% lysine in 16% protein, milo-soybean meal diets did not affect daily gains or feed efficiency.

Magruder et al. (1961) conducted a study to evaluate the effect of lysine and protein levels in both growing and finishing swine diets. The corn-soybean meal diets contained 14% protein reduced to 12% at

57 kg and 11% reduced to 9% at 57 kilograms. The addition of lysine improved growth and feed efficiency of pigs fed the lower protein diets but had no effect on performance of pigs fed the higher protein diets. In a second trial, pigs were fed corn-soybean meal diets with protein levels of 14-12% and 12.5-10.5%. The addition of .1% lysine to the low protein diets improved average daily gain significantly so that it nearly equalled that of pigs fed the 14-12% protein.

In summary, the N.R.C. (1973) recommends .7% lysine in a 16% protein diet for growing swine (20 to 35 kg). Using average values for lysine content of corn and soybean meal, a 16% protein, corn-soy diet will provide approximately .78% lysine, while a 14% diet will provide about .05% less than the .7% required. The lysine recommendation for finishing swine is .57% in diets of 13% crude protein.

<u>Energy</u>

The energy level in the nonruminant diet can be altered most easily by either adding fiber to decrease digestible energy or by the addition of plant or animal fat to increase energy. The addition of fat is the change most often made in growing and finishing swine diets.

The effect of increasing energy in the diet and its effect on rate of gain have been somewhat inconclusive. Heitman (1956) reported that adding 10% fat to growing and finishing swine diets increased rate of gain significantly over pigs fed nonfat diets. The 10% fat diet, however, did not support gains that were significantly faster than those obtained from a 5% fat diet. Wagner <u>et al</u>. (1963) observed that increasing dietary energy from 2090 kcal/kg to 2574 kcal/kg for growing swine increased rate of gain, but increasing energy from 2882 to 3608 kcal/kg resulted in no significant increase in gain. Studies with feeding levels of up to 20% fat in the diet were shown to significantly increase rate of gain by Kennington et al. (1958). Cooke et al. (1972) reported that as energy increased (2830, 3100, 3375 and 3585 kcal/kg) there was a linear increase in rate of gain for growing pigs. Waldern (1964), working with finishing pigs with an initial weight of 50 kg, found they gained .15 kg per day more on a high energy diet than when fed a lower energy diet.

In contrast to the above research, Baird et al. (1958) found no significant differences in rate of gain due to increasing energy levels in diets for growing and finishing swine. Similar results were reported by Seerley et al. (1964) for growing and finishing swine and Owen and Ridgeman (1967) with finishing pigs, as both found no advantage in growth as energy levels of the diet increased.

Kennington et al. (1958), Pond et al. (1960) and Kuryvial et al. (1962) all reported that, as energy was increased with the use of additional fat in growing and finishing swine diets, feed consumption was reduced. Cole et al. (1967) fed diets containing energy levels of 3910, 3630, 3356 and 2970 kcal/kg and noted increases in daily feed consumption from 2.80 to 3.65 kg as energy level decreased. Actual energy intakes were 10,060, 10,720, 10,550 and 9,770 kcal for diets containing 3910, 3630, 3356 and 2970 kcal/kg, respectively. There were no significant differences in digestible energy consumption between energy levels, indicating that the pigs consumed the feed to meet their energy requirement. Further evidence in this regard was reported by Owen and Ridgeman (1967), who found that finishing pigs fed a high fiber, low energy diet increased feed consumption until they were consuming as much energy as finishing pigs on a normal energy diet. An exception to these results is the report of Heitman (1956), who indicated that, as fat was increased to 5 and 10% of the diet, no difference in feed consumed per day was found.

The earliest and easiest demonstrated result of feeding high energy diets is an increase in feed efficiency. Baird et al. (1958) first reported that, although no increase in gain was observed due to increased caloric density, feed efficiency was improved. Kennington et al. (1958), Bowland and Berg (1959), Noland and Scott (1960), Kuryvial et al. (1962), Clawson et al. (1962), Wagner et al. (1963), Seerley et al. (1964) and Cooke (1972) all found that as dietary energy was increased, primarily by the addition of animal fat, the amount of feed required per kg of gain decreased in both growing and finishing swine diets.

The increase in feed efficiency from the addition of fat to the diet has been postulated to be due to increased digestibility of other nutrients in the diet. Greeley et al. (1964) reported that protein digestibility was unaffected by source or level of fat as stabilized lard, stabilized animal tallow or crude corn oil fed at 0, 5, 10 or 15% of the diet. Lowery et al. (1962) demonstrated no increase in fat digestibility with increased fat in the diet. In contrast, Boenker et al. (1969) found fat had little effect on digestibility of various dietary components, except the digestibility of ether extract increased as level of fat increased. Lowering of the dietary energy levels by adding 10% corn cobs increased fecal nitrogen by 10% and reduced digestible energy of the diet by a maximum of 5%.

Differences between various energy sources, molasses, sugar, corn, tallow, soybean oil and mixed fats, were studied by Brooks (1972). Feed efficiency was found to be completely dependent upon energy level regardless of source. Hamilton and McDonald (1969), working with weanling pigs, reported that dietary fat source did not affect average daily gain, feed/gain or apparent digestibility of protein, dry matter or fat. Digestibility of fatty acids was found to be high for all except stearic and palmitic.

Calorie:Protein Relationship

The most desirable calorie:protein ratio has never been established in swine diets as it has for the chick. Hill and Dansky (1950) reported that, as the energy level of the diet increased, the chick tended to consume less feed. The protein requirement for growth in chicks appears to be a relatively absolute quantity; but, as energy level increased and feed consumption decreased, a higher percent protein is needed to meet the chick's requirement for protein. This indicates that the interrelationship between calories and protein in chicks may be due more to its effect on feed consumption than actual influence on protein digestibility.

The addition of fat at 10% to low protein (12 to 14%) and high protein (18 to 20%) diets was studied in growing pigs by Pond *et al.*

(1960). The addition of 10% beef tallow promoted significantly better gain than low energy diets in the presence of high but not low protein. In similar work conducted by Noland and Scott (1960) using growing and finishing pigs, three protein levels of 12, 16 and 20% and three energy levels, 2090, 2310 and 2640 kcal/kg, were fed. In the summer trial, increasing levels of energy resulted in faster gains at all levels of protein. In the winter trial during the growing phase on 12% protein diets, the gains of pigs were depressed as energy increased. This was not apparent for the whole trial. Results for the entire trial indicated increasing levels of energy resulted in faster gains at the 20% protein level only. Protein levels of 12 and 16% supported no faster gain for pigs fed the 2640 kcal diet than those fed the 2090 kcal diet. For the entire treatment period (summer and winter), diets with calorie:protein ratios of 108:1 to 165:1 produced gains slightly superior to the gains produced by ratios of 174:1 to 220:1 (kcal/kg ÷ percent protein).

Lowery _et al_. (1958) and Clawson _et al_. (1962) reported that in growing pigs of 17 to 20 kg initial weight low protein and high caloric intake supported the lowest gains and that high protein, high energy supported the most desirable gains. In work with finishing swine, Allee _et al_. (1976) found that adding fat to the diet at the expense of other ingredients and without a corresponding increase in protein resulted in a decrease in gain.

Kennington _et al_. (1958) found no fat x protein interaction. The effect of additional fat was the same across all protein levels and the calorie:protein ratio which varied from 194:1 to 330:1 (kcal/kg ÷ percent protein) did not affect any of the factors being evaluated.

Seerley et al. (1964) reported that in low energy diets pigs fed high protein (14.4%) diets gained 7.4% faster than pigs fed the low protein (12.5%) diets. The differences in average daily gain between high and low protein diets increased when supplemental fat was added to the diets. The average daily gain of pigs fed the high energy diets was 13% faster on diets of high protein compared to those of low protein. The increased difference in growth rate on the high energy diets appears to be due to an increase in daily gain on the high protein as well as a decrease in gain on the low protein diet.

Barnes et al. (1959) studied fat in relation to protein requirements in young pigs. Pigs were fed diets of 9 and 16% protein and 0 and 10% added fat. The pigs fed the high fat and low protein diet showed definite signs of protein malnutrition similar to kwashiorkor in human protein depreviation. The low protein-low energy diet produced no such signs and animals gained considerably faster on the low protein-low energy diet than on the low protein-high energy diet. Using a low protein diet (3%) and either 5 or 25% corn oil, Pond et al. (1965) demonstrated that pigs fed the low protein-high fat diet showed a more severe depression in serum proteins than those pigs fed low protein-low fat diets.

It has been demonstrated that energy controls feed intake in swine (Cole et al., 1967) and in the chick (Hill and Dansky, 1950), as they consume only enough feed to meet energy requirements. Barnes et al. (1959) and Lowery et al. (1958) observed that daily caloric intake was greatly decreased in growing pigs by increasing levels of dietary energy when protein level was inadequate (9.0%). Clawson (1967) reported that weanling pigs fed diets containing 14.8% protein consumed more calories than those fed 9.0% protein diets. This was true at each dietary energy level. Pigs fed 10 and 20% added fat consumed fewer calories than those with no added fat in their diet. Daily caloric intake was reduced by increasing levels of dietary energy when protein was low. Kuryvial et al. (1962) reported an energy by protein interaction in regard to feed consumption. As fat levels increased (0, 15 or 30%) or as protein levels decreased (14, 18 or 22%), the daily feed consumption decreased.

Bowland and Berg (1959) found an increased consumption of low energy diets by finishing pigs with a lower feed intake by animals fed high energy diets. Protein level (12.5 to 21.0%) had no influence on consumption. Seerley et al. (1964) found similar results with both growing and finishing swine, as energy intake remained essentially equal for all diets irregardless of protein or energy level.

In general, as energy of the diet is increased, feed efficiency is also increased. Bowland and Berg (1959) reported that high energy diets resulted in improved feed efficiency for finishing swine. In addition, high protein alone or in combination with high energy also improved feed efficiency. Lowery et al. (1958) found that growing pigs fed higher protein, high energy diets further increased feed efficiency over that obtained on lower protein, high energy diets.

Diets fed to finishing swine showed a similar trend as was reported by Allee *et al*. (1976).

Increased feed efficiency due to higher energy content of the diet has never been fully explained. Pond *et al*. (1960) indicated that protein required per pound of gain was significantly greater for pigs fed diets of high protein (18 to 20%) than for those fed low protein (10 to 12%) but was significantly reduced by the addition of fat at either protein level. Lowery *et al*. (1958) reported that protein digestibility was increased by the addition of dietary fat. However, Lowery *et al*. (1963) reported that protein digestibility was not affected by either source of protein or level of energy.

Likuski *et al*. (1961) studied pigs fed two levels of energy (3.9 and 3.2 mcal/g) and two protein levels (14 and 18%). Nitrogen digestibility was reduced in pigs and rats fed lower energy diets. Retention of digested nitrogen was reduced with higher energy as compared to lower energy diets. In two experiments, Kuryvial *et al*. (1962) studied the requirement for apparent digestible energy per kg of gain (ADE/kg) as related to protein and energy. Results showed that the requirement for ADE/kg of gain decreased as fat level increased, indicating that pigs were more efficiently utilizing the ADE from fat than from the basal diet. It was further reported that fat levels did not influence apparent digestible energy coefficients or nitrogen retention.

Calorie:Lysine Relationship

Lysine has been determined to be the first limiting amino acid in corn-soy diets for growing and finishing swine. Lysine is therefore an important constituent when considering protein quality and a short discussion pertaining to protein quality and energy levels will precede the lysine-energy relationship discussion.

The importance of protein quality in swine diets in relation to energy was explored in young pigs by Lowery *et al*. (1962, 1963). In the first experiment, 5% protein was provided from two sources, a high quality protein (casein) and a low quality protein (purified wheat gluten). Fat was added at levels of 3 and 23%. The diet with casein containing 3% fat supported gains of 182 g per day for the entire treatment period. Pigs fed the diet with casein and 23% supplementary fat gained weight for 8 weeks and then plateaued and remained at a constant weight. Pigs fed the wheat gluten diet did not maintain their weight with either 3 or 23% added fat in the diet. In the second study, 5 and 18% protein were provided from either casein or purified wheat gluten and corn oil was added at 3, 13 and 23% of the diet. An increase in growth was observed on the casein diet as energy increased, especially at 18% protein. However, a depression in gain occurred with the wheat gluten diets, especially at the 23% corn oil level, indicating that protein quality is important in the utilization of high energy diets.

Clawson (1967) studied caloric intake in young and growing pigs. Protein quality was changed by increasing or decreasing the amount of protein provided by soybean meal. For young pigs, daily intake of metabolizable energy was not significantly influenced by protein level (10 vs 14%) as long as protein quality was equalized. Diets with 10% protein of lower quality reduced caloric intake.

Williams and Grau (1953), working with chicks, fed a 15% low lysine, sesame meal diet and varied cellulose and glucose to increase or decrease energy. Growth rates, caloric efficiency, protein efficiency and lysine efficiency increased as energy level of the diet decreased and feed intake increased.

Robinson et al. (1964) found daily live weight gain was more closely related to lysine level than to protein when the diets contained 3080 and 2860 kcal per kilogram. Maximum growth was obtained in these diets with a level of 1.05% lysine, while with diets containing an energy level of 3250 and 2620 kcal/kg maximum response was obtained with .9% lysine in 18% crude protein diets.

Abernathy et al. (1958) studied protein, lysine and energy relationships. The diets contained two protein levels (14 and 18%), two levels of added lysine (0 and .1%) and three fat levels (0, 5 and 10%) in a 2 x 2 x 3 factorial experiment. During the first 42 days (growing period), pigs fed the 18% protein diet gained significantly faster than those fed the 14% protein diet. The addition of L-lysine resulted in a depression in rate of gain. This depression appeared to be reduced as the caloric density of the diet increased. Feed efficiency increased as energy level increased, but no significant differences were observed due to added lysine. Mitchell et al. (1965a) evaluated a 16% protein diet containing five lysine levels (.54, .64, .74, .94 and 1.14%) in relation to three energy levels (2926, 3267 and 3717 kcal/kg). As lysine levels increased, a significant increase in daily gain was observed, with feed efficiency also improving as lysine and energy levels increased. Lysine requirement was calculated to be equal to .23% per 1000 kcal metabolizable energy (ME). Similar trends in feed efficiency have been reported by Clawson (1967), as feed per gain was improved by the addition of animal fat and also by the addition of lysine.

MATERIALS AND METHODS

Two experiments were conducted to evaluate the effect of energy levels on lysine requirements of growing and finishing swine. Two hundred four pigs were utilized through the two experimental periods. The experimental periods lasted for approximately 13 weeks. The first 5 weeks pigs were on the growing phase of the experiment. Pigs were then removed from experiment and placed on a 16% protein diet for 3 weeks, after which they were reallotted to the finishing phase for 5 weeks. Pigs that became undesirable because of weight or soundness were replaced by pigs of the same ancestry and nutritional background but of a more representative weight for the finishing phase. The only point at which these animals were used was to replace animals for allotment to the finishing phase.

Allotment of experimental animals was on the basis of sex, weight and ancestry. Each phase consisted of 12 treatments with two replicates per treatment. Four pigs were allotted to each treatment group (2 barrows and 2 gilts), except for the first replicate in the growing phase of experiment 1, where 5 pigs (2 barrows and 3 gilts) were allotted to each dietary treatment.

Housing for the experimental animals consisted of a wooden, uninsulated building set on concrete with straw or sawdust as bedding. Pens in the building were 1.8 x 2.4 meters. The connecting outside, concrete lots which contained the feeders and waterers were 1.8 x 3.7 m, to which animals had access at all times. Feed and water were provided *ad libitum*.

Diets were ground to a fineness of 4.8 mm, sacked and weighed at the university feed mill. Yellow grease and corn starch were used to vary dietary energy. Energy was increased by substituting the fat for corn starch at 5% of the diet. Final dietary energy levels were calculated for the growing diets to be approximately 3.46 and 3.68 and the finishing diets were 3.49 and 3.72 mcal/kg digestible energy (DE) for the starch and fat diets, respectively. L-lysine supplementation was achieved by adding L-lysine monohydrochloride (78% L-lysine) to the diet. The lysine was mixed with the vitamin premix prior to addition to the diet at the feed mill. The fat was melted at the poultry unit and transported to the feed unit where it was mixed into the feed.

Experimental animals fro the first experiment were Duroc, Hampshire and Yorkshire crossbred pigs farrowed at the university swine unit. Animals used in the second experiment were crossbred feeder pigs purchased at approximately 18.2 kilograms. All pigs had been treated for internal parasites prior to being placed on experiment.

Experiment 1 - Growing Phase

One hundred eight crossbred pigs weighing approximately 23 kg were used in the growing phase of experiment 1. The experiment was conducted from August 22, 1975, to October 7, 1975. Treatments consisted of two energy levels and six lysine levels within each energy level. Diets were as follows:

Diets 1-6 - Low energy, corn-soy-starch

Diets 7-12 - High energy, corn-soy-fat

	Lysine content, %
Diets 1 and 7	.60
Diets 2 and 8	.65
Diets 3 and 9	.70
Diets 4 and 10	.75
Diets 5 and 11	.80
Diets 6 and 12	.85

The composition of the basal diets used in the growing phase is shown in table 1. The low protein (13%) diets contained .6% lysine. Additions of L-lysine at increments of .05% were made to obtain the different dietary lysine levels.

TABLE 1. COMPOSITION OF GROWING DIETS EXPERIMENT 1 (PERCENT)

Ingredients	Diet no. 1-6	Diet no. 7-12
Corn	77.6	77.6
Soybean meal, 44%	14.1	14.1
Corn starch	5.0	--
Fat	--	5.0
Trace mineralized salt[a]	.5	.5
Dicalcium phosphate	1.3	1.3
Limestone	1.0	1.0
Premix[b]	.5	.5

[a] Contained .8% zinc.

[b] Supplied per kg of diet: vitamin A, 3300 IU; vitamin D, 330 IU; vitamin E, 11 IU; riboflavin, 2.75 mg; pantothenic acid, 11 mg; niacin, 17.6 mg; choline, 55 mg; vitamin B_{12}, 11 mcg and Aureomycin, 22 milligrams.

Experiment 2 - Growing Phase

Ninety-six pigs were allotted to the 12 replicated treatments in the growing phase of experiment 2 which began June 7, 1976, and ended July 22, 1976. Treatments again consisted of two energy levels and six lysine levels within each energy level. Average weight of the pigs was approximately 21.1 kilograms. Treatments were as follows:

Diets 1-6 - Low energy, corn-soy-starch

Diets 7-12 - High energy, corn-soy-fat

	Lysine content, %
Diets 1 and 7	.50
Diets 2 and 8	.55
Diets 3 and 9	.60
Diets 4 and 10	.65
Diets 5 and 11	.70
Diets 6 and 12	.75

The composition of the basal diets used in this experiment is shown in table 2. L-lysine was added to the basal diet which contained .5% lysine in .05% increments up to a level of .75% lysine.

Experiments 1 and 2 - Finishing Phase

The same dietary treatments were used in the finishing phase for both experiments 1 and 2. The first experiment was initiated October 21, 1975, and terminated December 12, 1975. The second experiment was started August 12, 1976, and ended September 24, 1976. The pigs in the first experiment weighed an average of approximately 73 kg and those in the second experiment averaged 57.3 kg initially. Treatments again

TABLE 2. COMPOSITION OF GROWING DIETS
EXPERIMENT 2 (PERCENT)

Ingredients	Diet no. 1-6	Diet no. 7-12
Corn	81.6	81.6
Soybean meal, 44%	10.1	10.1
Corn starch	5.0	--
Fat	--	5.0
Trace mineralized salt[a]	.5	.5
Dicalcium phosphate	1.3	1.3
Limestone	1.0	1.0
Premix[b]	.5	.5

[a] See table 1.
[b] See table 1.

consisted of two energy levels and six lysine levels within each energy level. The experimental treatments were as follows:

Diets 1-6 - Low energy, corn-soy-starch

Diets 7-12 - High energy, corn-soy-fat

	Lysine content, %
Diets 1 and 7	.40
Diets 2 and 8	.45
Diets 3 and 9	.50
Diets 4 and 10	.55
Diets 5 and 11	.60
Diets 6 and 12	.65

The composition of the diets used in the finishing phase is shown in table 3. L-lysine was added to the basal diet which contained .40% lysine in .05% increments up to a level of .65% lysine.

One pig died during the experiment and was examined by the South Dakota State University Animal Disease Research and Diagnostic

TABLE 3. COMPOSITION OF FINISHING DIETS (PERCENT)

Ingredients	Diet no. 1-6	Diet no. 7-12
Corn	86.0	86.0
Soybean meal, 44%	6.2	6.2
Corn starch	5.0	--
Fat	--	5.0
Trace mineralized salt[a]	.5	.5
Dicalcium phosphate	1.1	1.1
Limestone	.7	.7
Premix[b]	.5	.5

[a] See table 1.
[b] See table 1.

Laboratory. Necropsy revealed a large blood clot in the peritoneal cavity. Feed consumption was corrected by substituting an average value of the feed consumed to time of death.

Animals were weighed weekly as were feeders with feed in to determine feed consumption. All feeders were weighed empty prior to the start of the experiment. Parameters evaluated were rate of gain, feed efficiency and feed consumption.

In addition, blood samples were taken at the end of each experiment. Blood was obtained by puncturing the anterior vena cava with a 2.5 to 3.8 cm 18 gauge needle and 5 ml syringe. Blood was transferred to test tubes where it was allowed to clot. Blood urea nitrogen was determined according to methods outlined by Sigma Chemical Company. All blood samples were analyzed the day they were taken except for the samples obtained after the growing phase of the second experiment. In this case, the blood was cooled as quickly as possible after the sample was taken. After clotting had taken place, the blood was centrifuged and serum removed and placed in other test tubes and frozen until analysis was possible.

Data were analyzed statistically by least squares analysis of variance as outlined by Steele and Torrie (1960). A probability level of less than .05 was accepted as being significant. An F test was used to detect significant differences. Single degree of freedom linear, quadratic, cubic, quartic and quintic tests were used where applicable.

RESULTS AND DISCUSSION

Experiment 1

Growing Phase. Feed and growth performance data for the growing phase are summarized in table 4 and statistical analyses for this period are reported in tables 5 and 6.

Average daily gain did not differ significantly among treatments. Gains of pigs fed diets containing .60 to .85% lysine varied from .65 to .72 kg daily for pigs fed the lower energy (3.46 mcal DE/kg) diets and from .65 to .74 kg for those pigs fed the higher energy (3.68 mcal DE/kg) diets. There was no consistent trend in gain due to dietary lysine levels. A highly significant difference ($P < .01$) in gain did exist between barrows and gilts as barrows outgained gilts .74 to .63 kg/day.

The results above would agree with work done by Magruder et al. (1961), who indicated that lysine additions to a 14% protein, corn-soy diet resulted in no significant increase in daily gain in 18-kg growing pigs. In contrast, Mitchell et al. (1965a), working with 16.5- to 22.7- kg pigs and varying both energy and lysine in 16% protein, corn-sesame meal diets, found increases in gain due to increased dietary lysine and also an increase in lysine requirement with increased dietary energy. This relationship resulted in increased lysine requirements as a percent of the diet, increasing from .65 to .77 to .80% for energy levels of 2.92, 3.27 and 3.72 mcal ME/kg, respectively. A relationship such as that observed by Mitchell et al. (1965a) did not exist in this experiment, possibly due to the lower

TABLE 4. GROWTH AND FEED PERFORMANCE DATA
EXPERIMENT 1, GROWING PHASE[a]

	Lysine content, %						Means for energy
	.60	.65	.70	.75	.80	.85	
Average daily gain, kg							
Low energy	.65	.72	.64	.68	.67	.65	.67
High energy	.68	.69	.70	.65	.74	.70	.70
Means for lysine	.66	.70	.67	.67	.70	.67	
Average daily feed, kg							
Low energy	1.91	2.08	1.85	1.99	1.83	1.84	1.92
High energy	1.77	2.02	1.82	1.78	1.98	1.84	1.87
Means for lysine	1.84	2.05	1.84	1.89	1.91	1.84	
Feed/gain[b]							
Low energy	3.00	2.92	2.90	2.96	2.76	2.81	2.89
High energy	2.64	2.96	2.60	2.78	2.70	2.67	2.73
Means for lysine	2.82	2.94	2.75	2.87	2.74	2.74	

[a] Average initial weight, 23 kilograms.
[b] Significant difference due to energy level ($P<.05$).

TABLE 5. MEAN SQUARES FOR BLOOD UREA NITROGEN
AND AVERAGE DAILY GAIN
EXPERIMENT 1, GROWING PHASE

Source	df	Mean squares	
		ADG	BUN
Fat	1	.0937	3.7986
Lysine	5	.0324	35.3775**
Linear 1		--	157.3758**
Quadratic 1		--	19.3820*
Cubic 1		--	6.7282
Quartic 1		--	.2671
Quintic 1		--	.9479
Sex	1	1.6146**	1.3051
Replicate	1	.0059	35.0575**
Fat x lysine	5	.0414	2.3679
Fat x sex	1	.0263	4.6629
Lysine x sex	5	.0656	5.2907
Lysine x fat x sex	5	.0404	6.3003
Fat x replicate	1	.2082	.2936
Lysine x replicate	5	.0262	1.7452
Lysine x fat x replicate	5	.0366	2.9575
Sex x replicate	1	.2510	.8634
Fat x sex x replicate	1	.0158	2.1819
Lysine x sex x replicate	5	.0280	3.3219
Fat x lysine x sex x replicate	5	.0407	1.2183
Error	60	.0929	4.2489

* $P < .05$.
** $P < .01$.

TABLE 6. MEAN SQUARES FOR AVERAGE DAILY GAIN AND FEED/GAIN EXPERIMENT 1, GROWING PHASE

Source	df	Mean squares ADG	Mean squares Feed/gain
Fat	1	.0715	.1700*
Lysine	5	.1305	.0278
Replicate	1	.0900	.0384
Fat x lysine	5	.0767	.0210
Fat x replicate	1	.0590	.0794
Lysine x replicate	5	.0262	.0507
Error	5	.0979	.0159

* $P < .05$.

protein level of the diet. Baker et al. (1975), using corn-sesame meal diets of either 12 or 16% protein, observed that for each 1% drop in protein the dietary lysine requirement for growing pigs decreased .02%. In addition, the largest difference Mitchell et al. (1965a) found was between the lower energy diets of 2.93 and 3.27 mcal ME/kg. The difference in lysine requirement between 3.27 and 3.72 mcal ME/kg was not as great. The diets used in this experiment were close to the medium and high energy diets with 3.46 and 3.68 mcal DE/kg converting to metabolizable energy values of 3.19 and 3.43 mcal/kg, respectively.

There were no significant differences in feed consumption among treatments. Feed consumption ranged from 1.83 to 2.08 kg/day for pigs fed the lower energy diets and from 1.77 to 2.02 kg/day for those fed the higher energy diets, with no consistent trend due to lysine level. Feed consumption was slightly decreased for the higher energy diets at 1.87 kg/day compared to 1.92 kg/day for the lower energy diets.

Many workers (Kennington et al., 1958; Pond et al., 1960; Kuryvial et al., 1962; Cole et al., 1967) have found that increased dietary energy results in decreased feed consumption. The pig appears to consume only the feed necessary to meet its energy requirements. Work done by Heitman (1956) was the only study found that reported added dietary energy did not decrease feed consumption.

Increasing dietary energy caused a significant ($P < .05$) decrease in feed required per kg of gain. Those pigs fed the higher energy diet required 2.73 kg of feed per kg of gain, while pigs fed the lower energy diets required 2.89 kg of feed per kg of gain. Combining the data for both energy levels indicated a slight decrease in feed/gain due to increasing dietary lysine levels. The lowest feed/gain ratio of 2.74 was obtained when pigs received the .80 and .85% lysine diets, while pigs fed the .65% lysine diets required the most feed/gain (2.94). The lower energy diets did improve in feed efficiency slightly as lysine was added to the diets. The required feed/gain decreased from 3.00 for diets containing .60% dietary lysine to 2.76 for those with .80% lysine. There was no consistent trend due to variations in lysine for the higher energy diets. The feed/gain ratio of 2.96 for pigs fed the .65% lysine supplemented diet was considerably higher than the feed/gain ratios of pigs fed the other dietary lysine levels, as 2.78 was the next highest recorded feed/gain ratio.

In studies with dietary energy in pig diets, Baird *et al.* (1958) reported that an increase in caloric density of the diet resulted in an increase in feed efficiency. Lysine additions to low protein (12%), corn-soybean meal diets in studies conducted by Mahan *et al.* (1973) resulted in increased feed efficiency. Cahilly *et al.* (1963) found that increasing lysine over .60% of the diet had its largest effect on improving feed efficiency in 16% protein diets. Studying the relationship between lysine and energy on feed efficiency, Mitchell et al. (1965a) found that energy levels of 2.93, 3.27 and 3.72 mcal ME/kg resulted in lysine requirements of .66, .71 and .85%, respectively, for maximum feed efficiency. In the present experiment, the best feed efficiencies on the lower energy diets were 2.76 and 2.81 kg of feed per kg of gain for pigs fed diets containing .80 and .85% lysine, respectively. The most desirable feed/gain ratio for pigs fed the higher energy diet was 2.60 for those fed the diet containing .70% lysine. The trend of an effect on feed efficiency of pigs fed the higher energy diet was not as pronounced as when pigs were fed the lower energy diets, where increasing lysine appears to have caused an increase in feed efficiency. Less dietary lysine was required for best feed efficiency for pigs fed the higher energy diets than for those fed the lower energy diets.

Blood urea nitrogen (BUN) data are presented in table 7 and the statistical analyses in table 5.

Blood urea nitrogen levels were significantly affected by dietary lysine levels. Increasing lysine in the diet resulted in linear ($P < .005$) and quadratic ($P < .05$) decreases in BUN levels. BUN decreased at a decreasing rate with increasing lysine levels and then plateaued at .70% lysine. Blood urea nitrogen values for pigs fed diets of .60 to .85% lysine varied from 15.15 to 11.06 mg/100 ml and averaged 12.63 mg/100 ml for the pigs fed the lower energy diets. Levels ranged from 14.89 to 10.56 mg/100 ml with an average of 12.25 mg/100 ml for pigs fed the higher energy diets of varying lysine

TABLE 7. BLOOD DATA. EXPERIMENT 1, GROWING PHASE

	Lysine content, %						Means for energy
	.60	.65	.70	.75	.80	.85	
Blood urea nitrogen, mg/100 ml[a]							
Low energy	15.15	13.02	11.95	12.22	12.37	11.06	12.63
High energy	14.89	13.06	12.11	11.74	10.56	11.13	12.25
Means for lysine	15.01	13.04	12.03	11.98	11.46	11.09	

[a] Significant difference due to lysine (linear, $P<.005$; quadratic, $P<.05$).

content. The differences were not significant. These values are all within the values of 5 to 20 mg/100 ml suggested as normal by Cornelius and Kaneko (1963).

The decrease in BUN levels with increased dietary lysine would seem to indicate that the pig utilized the protein more efficiently in the higher lysine containing diets. The BUN levels also plateaued at .70% dietary lysine for pigs fed the lower energy diets and did not plateau until .80% dietary lysine for those fed higher energy diets, indicating a possible increase in lysine requirement due to dietary energy for maximum reduction in BUN levels.

Finishing Phase. Growth and feed performance data are presented in table 8 and the statistical analyses are shown in tables 9 and 10.

There were no significant differences in average daily gains among treatments during this period. Pigs fed the lower energy diets varying in lysine content from .40 to .65% gained from .74 to .89 kg daily, while pigs fed the higher energy diets gained from .79 to .90 kg daily. The pigs fed the higher energy diets (3.72 mcal DE/kg) that contained .50% lysine gained 11% faster than those fed diets containing .40% lysine and 8% faster than those pigs fed diets with .45% lysine. A level of .45% lysine appeared to support optimum gains when the diets contained less energy (3.42 mcal DE/kg). Average daily gain decreased .1 kg per day when dietary lysine was increased from .55 to .60% and decreased an additional .05 kg when the diet was increased to .65% lysine.

TABLE 8. GROWTH AND FEED PERFORMANCE DATA FOR EXPERIMENT 1, FINISHING PHASE[a]

	Lysine content, %						Means for energy
	.40	.45	.50	.55	.60	.65	
Average daily gain, kg							
Low energy	.84	.88	.88	.89	.79	.74	.84
High energy	.79	.82	.89	.90	.90	.90	.86
Means for lysine	.81	.85	.89	.89	.85	.81	
Average daily feed, kg[b]							
Low energy	3.45	3.83	3.64	3.66	3.29	2.96	3.47
High energy	3.32	3.44	3.35	3.40	3.42	3.56	3.42
Means for lysine	3.39	3.64	3.49	3.53	3.35	3.26	
Feed/gain							
Low energy	4.14	4.42	4.14	4.12	4.13	4.04	4.17
High energy	4.22	4.18	3.78	3.80	3.80	4.00	3.96
Means for lysine	4.18	4.30	3.96	3.96	3.96	4.00	

[a] Average initial weight, 73 kilograms.

[b] Significant difference due to energy ($P<.05$); lysine treatment effect linear ($P<.01$), quadratic ($P<.01$), cubic ($P<.01$) and quintic ($P<.05$) and fat x lysine interaction ($P<.01$).

TABLE 9. MEAN SQUARES FOR BLOOD UREA NITROGEN AND AVERAGE DAILY GAIN EXPERIMENT 1, FINISHING PHASE

Source	df	Mean squares ADG	Mean squares BUN
Fat	1	.1148	15.7302
Lysine	5	.0906	18.7565
Sex	1	.1350	28.4273
Replicate	1	.3015*	1.6433
Fat x lysine	5	.1346	30.6292
Fat x sex	1	.0580	10.3097
Lysine x sex	5	.0387	29.1885
Fat x lysine x sex	5	.0921	23.6059
Fat x replicate	1	.1426	4.8330
Lysine x replicate	5	.0429	8.50122
Fat x lysine x replicate	5	.0329	15.6459
Sex x replicate	1	.0009	.1536
Fat x sex x replicate	1	.0782	1.1572
Lysine x sex x replicate	5	.0578	3.3872
Fat x lysine x sex x replicate	5	.0567	3.0267
Error	48	.0664	13.9178

* $P < .05$.

TABLE 10. MEAN SQUARES FOR AVERAGE DAILY FEED AND FEED/GAIN FOR EXPERIMENT 1, FINISHING PHASE

Source		df	Mean squares ADG	Feed/gain
Fat		1	.0852*	.2420
Lysine		5	.3486**	.0838
Linear	1		.5679**	--
Quadratic	1		.7600**	--
Cubic	1		.1602**	--
Quartic	1		.0472	--
Quintic	1		.1467**	--
Replicate		1	.002	.3243
Fat x lysine		5	.6529**	.0328
Fat x replicate		1	.4788**	.0012
Lysine x replicate		5	.2264**	.0698
Error		5	.0082	.0439

* $P < .05$.
** $P < .01$.

The fact that no significant differences were observed for increasing dietary lysine levels may be due to the heavy initial weight of the pigs (73 kg). Along with the weight, the low protein diet (10%) may have decreased lysine requirements to approximately .40%. Mitchell et al. (1965b) reported that the lysine requirement for maximum rate of gain of 50-kg finishing pigs was between .36 and .41% in 12% protein diets. Brown et al. (1973) found that maximum gain was achieved when feeding diets with .48% lysine. The differences in lysine requirements suggested by these authors may be due to differences in protein levels.

The addition of fat to the diet has been somewhat variable as to its effect on rate of gain. Research conducted by Owen and Ridgeman (1967) found no growth advantage due to adding fat to the diet. Waldern (1964) reported increased gains for higher energy diets fed to 50-kg finishing pigs. Wagner _et al_. (1963) observed that increasing energy from 2090 to 2574 kcal ME/kg in very low energy diets resulted in increased gains in growing pigs. However, increasing energy from 2882 to 3608 kcal ME/kg resulted in no significant increase in gains. The diets in this experiment contained 3.42 and 3.72 mcal DE/kg which supports the possibility that higher energy diets may not increase gain past a certain energy level.

Pigs fed diets containing 3.72 mcal DE/kg consumed significantly less daily feed than those pigs fed a dietary energy level of 3.42 mcal DE/kg. Feed consumption by pigs fed the lower energy diet averaged 3.47 kg/day compared to a consumption of 3.42 kg daily for pigs fed the higher energy diets. There was a significant linear ($P<.01$), quadratic ($P<.01$), cubic ($P<.05$) and quintic ($P<.05$) relationship between feed consumption and percent lysine in the diet. The lysine by energy interaction was also significant ($P<.01$) for feed consumption.

Feed consumption increased as dietary lysine increased in the higher energy diets, while feed consumption decreased with increasing dietary lysine levels when pigs were fed the lower energy diets, resulting in a significant lysine by energy interaction.

In addition to the above results, significant interactions ($P < .05$) were obtained for energy by replication and lysine by replication. This may be due to differences in environmental conditions during the time the two replicates were on experiment. The first replicate was removed from the experiment on November 24, 6 days after a severe snow storm. The second replicate remained on experiment until December 9. The temperature during the last weeks that the second replicate was on experiment was colder than that experienced by pigs in the first replicate and may have changed the consumption patterns of the pigs in the two replicates.

There were no significant differences in feed efficiency due to dietary lysine or energy. Feed/gain ratios for pigs fed diets containing .40 to .65% lysine varied from 4.42 to 4.04, averaging 4.17, for pigs fed the lower energy diets and from 4.22 to 3.78, averaging 3.96, for pigs fed the higher energy diets. Combining the data for both energy levels indicated that dietary lysine levels of .50 to .65% supported a decrease in feed required per kg of gain (3.96 to 4.00) compared to higher (4.18 and 4.30) feed/gain ratios for pigs fed .40 and .45% dietary lysine, respectively. The trend for feed efficiency was toward more efficient gains for pigs fed higher energy diets. Kennington et al. (1958) reported that, in diets containing 0 to 20% added fat to increase the dietary energy level, a significant decrease occurred in feed required per kg of gain. Kuryvial et al. (1962) reported that the addition of 15 and 30% supplemental fat to the diets of growing and finishing pigs resulted in improved feed efficiency.

Lysine was shown by Cahilly _et al_. (1963) to increase feed efficiency for corn-peanut oil meal diets, even at levels above that normally recommended for growing and finishing pigs. Mitchell _et al_. (1965b) further indicated that lysine requirements were higher for maximum feed efficiency than for maximum rate of gain in 50-kg finishing pigs. The results reported here are contrary to these findings. Pigs fed the high energy diets had optimum feed efficiency when fed diets containing .50% lysine, the same level which supported optimum gains on these diets. There was no trend in the feed efficiency observed among lysine treatments in the lower energy diets and it would appear .40% dietary lysine was as adequate as the higher levels. This compares with a level of .45% lysine suggested for best gains on the low energy diets.

Blood data are presented in table 11 and statistical analyses of these data are summarized in table 9.

No significant differences were observed for BUN levels due to dietary treatments. Pigs fed lower energy diets containing .40 to .65% lysine had BUN levels of 11.94 to 16.94 mg/100 ml compared to BUN levels of 11.39 to 15.94 mg/100 ml for pigs fed the higher energy diets with different lysine contents. There was a consistent trend toward lower BUN levels with increasing levels of lysine when the data were combined for pigs fed both dietary energy levels.

TABLE 11. BLOOD DATA. EXPERIMENT 1, FINISHING PHASE

	Lysine content, %						Means for energy
	.40	.45	.50	.55	.60	.65	
Blood urea nitrogen, mg/100 ml							
Low energy	13.59	14.71	15.38	16.94	14.53	11.94	14.51
High energy	15.61	15.94	14.14	11.39	11.39	12.60	13.71
Means for lysine	14.60	15.32	14.76	14.17	13.54	12.27	

Experiment 2

Growing Phase. Average daily gain, average daily feed consumed and feed/gain data are presented in table 12. Tables 13 and 14 report mean squares and significance data.

Variations in dietary energy and lysine level had no significant effect on rate of gain. Gains of pigs fed .50 to .75% lysine varied from .44 to .52 kg daily for diets containing 3.46 mcal DE/kg and from .45 to .49 kg daily for diets containing 3.68 mcal DE/kg. There was no definite trend observed in gains due to variations in lysine levels. Barrows gained significantly ($P<.05$) faster than gilts, .49 compared to .45 kg/day, respectively. Barrows fed lower energy diets gained .48 kg daily compared to .51 kg daily for those fed the higher energy diets. In contrast, average daily gain for gilts decreased from .49 to .41 kg daily with added dietary energy, resulting in a highly significant ($P<.01$) sex by energy interaction.

Corn-soybean meal diets of 12% protein were fed to growing pigs at an initial weight of 21 kg by Meade et al. (1966). The addition of L-lysine to these diets resulted in no increase in daily gain. This suggests that the addition of lysine to a 12% protein, corn-soy diet may result in an amino acid imbalance for growing pigs. Sharda et al. (1976) reported evidence to substantiate this possibility. These workers found the addition of lysine alone did not give maximum response when added to 12% protein, corn-soy diets for growing pigs, but that added tryptophan was also needed for maximum rate of gain. The lower energy diets in this experiment supported faster gains than

TABLE 12. GROWTH PERFORMANCE AND FEED DATA
EXPERIMENT 2, GROWING PHASE[a]

	Lysine content, %						Means for energy
	.50	.55	.60	.65	.70	.75	
Average daily gain, kg							
Low energy	.44	.48	.48	.51	.52	.47	.49
High energy	.45	.49	.45	.49	.45	.45	.46
Means for lysine	.45	.48	.46	.50	.49	.46	
Average daily feed, kg							
Low energy	1.40	1.43	1.49	1.49	1.51	1.36	1.45
High energy	1.32	1.49	1.24	1.38	1.22	1.24	1.32
Means for lysine	1.36	1.46	1.36	1.44	1.37	1.30	
Feed/gain ratio[b]							
Low energy	3.20	3.00	3.12	2.97	2.88	2.99	3.03
High energy	2.95	3.04	2.78	2.86	2.75	2.76	2.86
Means for lysine	3.08	3.02	2.95	2.92	2.82	2.88	

[a] Average initial weight, 21.1 kilograms.
[b] Significant differences due to energy ($P < .05$).

TABLE 13. MEAN SQUARES FOR AVERAGE DAILY GAIN AND BLOOD UREA NITROGEN
EXPERIMENT 2, GROWING PHASE

Source	df	Mean squares ADG	Mean squares BUN
Fat	1	.0578	319.3226*
Lysine	5	.0270	93.1014
Sex	1	.1958*	24.2009
Replicate	1	.6240**	249.9209*
Fat x lysine	5	.0197	107.1093
Fat x sex	1	.3456**	7.2744
Lysine x sex	5	.0129	18.8214
Fat x lysine x sex	5	.0421	30.7047
Fat x replicate	1	.0230	41.9266
Lysine x replicate	5	.0949	80.9066
Fat x lysine x replicate	5	.0796	117.954
Sex x replicate	1	.0162	6.1250
Fat x sex x replicate	1	.0183	19.8450
Lysine x sex x replicate	5	.0202	10.8550
Fat x lysine x sex x replicate	5	.1557	34.6844
Error	47	.0365	43.8205

* $P < .05$.
** $P < .01$.

TABLE 14. MEAN SQUARES FOR AVERAGE DAILY FEED AND FEED/GAIN
EXPERIMENT 2, GROWING PHASE

		Mean squares	
Source	df	ADG	BUN
Fat	1	.5133	.1700*
Lysine	5	.0612	.0359
Replicate	1	.1751	.6080**
Fat x lysine	5	.0754	.0181
Fat x replicate	1	.0287	.0081
Lysine x replicate	5	.1267	.0334
Error	5	.0938	.0196

* $P < .05$.
** $P < .01$.

the higher energy diets (.49 vs .46 kg/day). Noland and Scott (1960) reported that the addition of fat to low protein diets did not result in faster gains and in some instances on 12% protein diets actually caused a significant decrease in daily gain.

Average daily feed consumed did not differ significantly among variations in dietary energy and lysine. Feed consumption ranged from 1.36 to 1.51 kg daily for pigs fed the lower energy diets and 1.22 to 1.49 kg daily for pigs fed the higher energy diets. There were no definite trends for feed consumption due to variations in dietary lysine. Feed consumption, 1.32 kg daily, was slightly less for pigs fed the higher energy diets as compared to 1.45 kg daily for those fed the lower energy diets.

Cole et al. (1967) reported that increasing energy in diets decreased the amount of feed consumed so the actual energy intake remained constant. For this experiment, pigs fed the higher energy diet consumed 4.86 mcal of digestible energy daily compared to 5.02 mcal daily for those receiving the low energy diets. Clawson et al. (1967) reported that daily caloric intake was reduced when pigs were fed 10 and 20% added fat when compared to those receiving no additional fat in the diet.

The addition of fat to increase caloric density of the diet resulted in a significant ($P < .05$) decrease in feed required per kg of gain. The feed/gain ratio decreased from 3.05 for pigs fed lower energy diets to 2.86 for those fed higher energy diets. Combining data for pigs fed both energy levels indicated less feed required for gain by pigs fed .70% lysine diets with a feed/gain ratio of 2.82. Pigs fed the .50% lysine diets required the most feed/gain (3.08). Feed efficiency for lysine varied from 2.88 to 3.20 for the lower energy diets and from 2.75 to 3.04 for the higher energy diets. The differences were not significant. In both the higher and lower energy diets, increasing dietary lysine to .70% resulted in a slight decrease in feed/gain.

Results reported by Greeley et al. (1964) and Seerley et al. (1964) using growing pigs indicate that, as energy levels in the diet increased by adding dietary fat, feed required per kg decreased. Cahilly et al. (1963) indicated that increasing lysine levels over that required for maximum rate of gain had its largest effect on improving feed efficiency. For the experiment reported herein, maximum rate of gain occurred with pigs fed diets containing .65% lysine, while maximum feed efficiency was obtained from pigs fed diets containing .70% lysine, indicating a possible increase in lysine requirement for maximum feed efficiency.

Results for blood urea nitrogen are reported in table 15 and table 13 shows the statistical analyses and mean squares.

Pigs fed the higher energy diets had significantly ($P < .05$) lower BUN levels than pigs fed the lower energy diets (20.45 vs 24.13 mg/100 ml). When energy levels were combined, variations in dietary lysine resulted in a slight decrease in BUN levels with increased lysine intake. The lowest BUN level was 18.46 mg/100 ml for pigs fed .70% lysine and the highest BUN level was 25.52 mg/100 ml for animals receiving .45% dietary lysine. The lowest BUN level for pigs fed the low energy diets was 21.09 mg/100 ml for those fed diets of .60% lysine and the lowest for those fed the higher energy diets was 13.25 mg/100 ml for pigs fed .70% dietary lysine.

The decrease in BUN levels for the higher energy diets would indicate that the pig is more efficiently utilizing its dietary protein with higher energy diets. The changes in BUN levels due to variations in dietary lysine for higher and lower energy diets would indicate that the requirement for lysine increased with an increase in dietary energy. The levels were somewhat higher than obtained in previous parts of this experiment. When feeding pigs high and low protein diets (4 and 16% protein), Tumbleson et al. (1972) found no differences due to percent

TABLE 15. BLOOD DATA. EXPERIMENT 2, GROWING PHASE

	Lysine content, %						Means for energy
	.50	.55	.60	.65	.70	.75	
Blood urea nitrogen, mg/100 ml[a]							
Low energy	22.45	29.24	21.09	23.16	23.68	25.18	24.13
High energy	25.88	21.80	22.28	19.26	13.25	20.21	20.45
Means for lysine	24.16	25.52	21.68	21.21	18.46	22.69	

[a] Significant effect due to energy ($P < .05$).

dietary protein. These results would suggest that the lower lysine levels in this experiment may not have been responsible for the increased BUN levels. The samples were stored, however, as frozen serum for 2 weeks before analysis and this may have resulted in higher BUN levels due to partial breakdown of some of the serum proteins.

Finishing Phase. Results for growth performance and feed data are reported in table 16. The summary of the statistical analyses is shown in tables 17 and 18.

There were no significant differences in average daily gain due to variations in dietary energy or lysine. Pigs fed the lower energy diets (3.49 mcal DE/kg) varying in lysine content from .40 to .65% gained from .72 to .82 kg daily, while pigs fed the higher energy diets gained from .64 to .78 kg/day. Average daily gains for pigs fed the lower energy diets averaged .76 kg daily and those fed the higher energy diets .70 kg daily. The decrease in gain for the higher energy diet was due primarily to the decrease in gain for pigs fed this diet with the higher lysine levels. Gains of .69, .66 and .64 kg daily were obtained for pigs fed dietary lysine levels of .55, .60 and .65%, respectively, on the higher energy diets, and gains of .82, .79 and .77 kg daily were obtained when pigs were fed the same dietary lysine levels in diets of lower energy content. Combining energy levels resulted in no consistent trends for gain due to variations in dietary lysine. Barrows gained .82 kg daily compared to .65 kg daily for the gilts. This difference was significant ($P < .05$).

TABLE 16. GROWTH PERFORMANCE AND FEED DATA
EXPERIMENT 2, FINISHING PHASE[a]

	Lysine content, %						Means for energy
	.40	.45	.50	.55	.60	.65	
Average daily gain, kg							
Low energy	.72	.74	.76	.82	.79	.77	.76
High energy	.70	.78	.76	.69	.66	.64	.70
Means for lysine	.71	.76	.76	.75	.72	.71	
Average daily feed, kg[b]							
Low energy	2.69	2.57	2.68	2.79	2.44	2.42	2.59
High energy	2.37	2.56	2.49	2.21	2.24	2.05	2.32
Means for lysine	2.52	2.57	2.58	2.50	2.34	2.24	
Feed/gain							
Low energy	3.76	3.50	3.50	3.43	3.10	3.15	3.41
High energy	3.39	3.30	3.29	3.21	3.42	3.22	3.30
Means for lysine	3.57	3.40	3.40	3.32	3.25	3.18	

[a] Average initial weight, 57 kilograms.
[b] Significant differences due to energy ($P < .05$).

TABLE 17. MEAN SQUARES FOR AVERAGE DAILY GAIN AND BLOOD UREA NITROGEN EXPERIMENT 2, FINISHING PHASE

Source		df	Mean squares	
			ADG	BUN
Fat		1	.4082	2.2817
Lysine		5	.0494	23.9647*
Linear	1		--	77.3851**
Quadratic	1		--	4.7850
Cubic	1		--	16.5920
Quartic	1		--	.0001
Quintic	1		--	21.0600
Sex		1	3.2487**	.3038
Replicate		1	.0035	4.3350
Fat x lysine		5	.1084	12.3894
Fat x sex		1	.0088	14.1067
Lysine x sex		5	.0356	9.5675
Lysine x fat x sex		5	.0461	16.0119
Fat x replicate		1	.4988	2.2204
Lysine x replicate		5	.0727	2.4457
Fat x lysine x replicate		5	.0354	26.8647
Sex x replicate		1	.1233	5.4150
Fat x sex x replicate		1	.0176	17.8538
Lysine x sex x replicate		5	.0284	22.7852
Fat x lysine x sex x replicate		5	.1155	10.4795
Error		48	.1345	9.5927

* P <.05.
** P <.01.

TABLE 18. MEAN SQUARES FOR AVERAGE DAILY FEED AND FEED/GAIN
EXPERIMENT 2, FINISHING PHASE

Source	df	Mean squares	
		ADG	Feed/gain
Fat	1	2.2632*	.0693
Lysine	5	.3803	.0742
Replicate	1	.0551	.0459
Fat x lysine	5	.1831	.0594
Fat x replicate	1	.6048	.0782
Lysine x replicate	5	.0691	.0312
Error	5	.1958	.2310

* $P < .05$.

Pigs were fed a low protein diet of 10%. The N.R.C. (1973) recommends a 13% protein diet for finishing pigs. The low protein may have decreased the requirement for lysine similar to findings reported by Baker et al. (1975) and Brinegar et al. (1950), indicating a decrease in protein as a percent of the diet reduced the requirement for dietary lysine.

A significant difference ($P < .05$) in feed consumption was demonstrated for variations in dietary energy. Pigs fed diets containing 3.72 mcal DE/kg consumed less feed than the pigs fed a dietary energy level of 3.49 mcal DE/kg. Feed consumption by the pigs fed the lower energy diets averaged 2.59 kg/day, 12% more than the 2.32 kg/day consumed by those fed the higher energy diets. Feed consumption of pigs fed diets containing .40 to .65% lysine ranged from 2.47 to 2.79

kg daily for the lower energy diets and from 2.05 to 2.56 kg for the higher energy diets. Pigs fed the higher energy diets consumed less feed as dietary lysine levels increased. This trend was especially pronounced as pigs fed .55, .60 and .65% lysine in the diets consumed 2.21, 2.24 and 2.05 kg of feed daily compared to 2.37, 2.56 and 2.49 kg of feed daily for pigs fed diets with .40, .45 and .50% lysine, respectively. Pigs fed the higher energy diets consumed 21, 8 and 15% less feed than that consumed by pigs fed the lower energy diets with .55, .60 and .65% lysine. Lysine levels of .60 and .65% were consumed at lower levels than those diets of lower lysine content when energy diets were combined. Feed consumption was similar for pigs fed .40 to .55% lysine and ranged from 2.50 to 2.58 kg of feed daily.

The pigs fed the higher energy diets consumed less feed, which agrees with work done by Kennington _et al_. (1958), Pond _et al_. (1960) and Kuryvial _et al_. (1962). Hill and Dansky (1950) in work with the chick reported that increasing energy increased the percent protein required in the diet by decreasing the amount of feed consumed. In this experiment, the increased energy in the diet resulted in decreased feed consumption and may have caused an amino acid imbalance at the higher dietary lysine levels, which resulted in decreased feed consumption. This decrease in feed consumption may have resulted in the lower rate of gain observed earlier.

Pigs utilized in this experiment had a lower initial weight (57 kg) than those in the finishing phase of the first experiment (73 kg). The lighter initial weight in addition to the higher temperatures encountered in the summer may, in part, be responsible for the pigs on this experiment gaining slower than the pigs in the first experiment (.73 vs .85 kg/day). In addition, the pigs consumed less feed (2.46 vs 3.44 kg/day), which may have resulted in the decreased gain reported above.

There were no significant differences in feed efficiency among dietary treatments. Feed required per kg of gain for pigs fed diets containing .40 to .65% dietary lysine varied from 3.10 to 3.76 for the lower energy diets and from 3.21 to 3.42 for the higher energy diets. Average feed/gain for the higher energy diets was slightly less than for the lower energy diets (3.30 vs 3.41). Combining energy and evaluating variations in dietary lysine indicated that as lysine levels increased the feed/gain ratio decreased. Feed/gain ratios varied from 3.57 for pigs fed diets containing .40% lysine to 3.18 for pigs fed diets with .65% lysine.

Work reported by Aldinger and Roberts (1973) indicated that the addition of .1% L-lysine to an 11% protein, corn-soy diet decreased feed required per kg of gain to 3.22 from 3.43. The addition of .1% L-lysine to a 13% protein diet in the same experiment decreased the feed/gain ratio from 3.29 to 3.11. This tends to support the results found here that increasing lysine may reduce the amount of feed required for gain.

Data for blood urea nitrogen levels are presented in table 19 and the statistical analyses in table 14.

TABLE 19. BLOOD DATA. EXPERIMENT 2, FINISHING PHASE

	Lysine content, %						Means for energy
	.40	.45	.50	.55	.60	.65	
Blood urea nitrogen, mg/100 ml[a]							
Low energy	12.65	13.80	12.29	13.62	9.89	12.64	12.48
High energy	14.32	14.10	11.58	10.86	11.29	10.89	12.17
Means for lysine	13.49	13.95	11.93	12.24	10.59	11.76	

[a] Significant difference due to lysine (linear, $P<.05$).

Increasing dietary lysine resulted in a linear ($P<.05$) decrease in BUN levels when energy levels were combined. Dietary lysine levels of .40 to .65% in .05% increments resulted in BUN levels of 13.49, 13.95, 11.93, 12.24, 10.59 and 11.76 mg/100 ml for each .05% increment, respectively. Energy levels of 3.49 and 3.72 mcal DE/kg resulted in BUN levels of 12.48 and 12.17 mg/100 ml, respectively. The difference was not significant.

Pigs fed diets of .40 to .65% lysine had reduced BUN levels with increasing dietary lysine. This may be due to increased utilization of the dietary protein. Mahan _et al_. (1973) reported increased nitrogen retention and increased feed efficiency with added lysine, which would indicate more efficient use of dietary protein. The results of this portion of the experiment would indicate a similar response, as BUN levels decreased and feed efficiency increased with increased dietary lysine.

SUMMARY

Two hundred four crossbred pigs (96 barrows and 108 gilts) were utilized to study the effect of lysine and energy in low protein diets. The experiments each consisted of a growing and a finishing phase. The criteria used to measure the effect of dietary lysine and energy levels were growth rate, feed consumption, feed efficiency and blood urea nitrogen.

Diets fed during the growing phase were increased in energy content from 3.46 to 3.68 mcal DE/kg by replacing starch with animal fat. Six levels of dietary lysine were fed in combination with each energy level. The growing phase consisted of feeding diets containing lysine levels of .60 to .85% in .05% increments for experiment 1 and lysine levels of .50 to .75% in .05% increments for experiment 2.

There was no significant effect of dietary lysine level on average daily gain during the growing phase in either experiment. In experiment 1, gain varied from .66 to .70 kg daily for pigs weighing 23 kg initially. Gains were less, .45 to .50 kg daily, in the second experiment conducted with pigs of 21-kg initial weight. Variation in dietary energy had no significant effect on rate of gain. Pigs fed the lower energy diet in experiment 1 gained .67 kg daily on the higher energy diet. In experiment 2, the pigs fed the higher dietary energy gained slower, .46 kg daily, while pigs fed the lower energy diets gained .49 kg daily.

Average daily feed consumed was not affected by lysine or energy in either growing experiment. Feed consumption due to variation

in lysine ranged from 1.84 to 2.05 kg daily in experiment 1 and from 1.30 to 1.46 kg daily in experiment 2. In both experiments, increased dietary energy resulted in decreased feed consumption. In experiment 1 consumption decreased from 1.92 to 1.87 kg/day and in experiment 2 from 1.45 to 1.32 kg/day.

Dietary energy significantly ($P<.05$) affected feed efficiency for the growing pigs. Increased dietary energy reduced the feed/gain ratio in experiment 1 from 2.89 to 2.73 and in experiment 2 from 3.03 to 2.86. Feed/gain was not significantly affected by dietary lysine. Feed/gain ratios varied from a low of 2.74 for pigs fed diets with .80 and .85% lysine to 2.94 for those fed diets with .65% lysine in experiment 1 and from 3.08 for .50% lysine to 2.82 for .70% lysine in experiment 2.

Blood urea nitrogen levels in experiment 1 decreased as dietary lysine increased. The effect of dietary lysine on BUN levels was linear ($P<.005$) and quadratic ($P<.05$), as the BUN levels decreased at a decreasing rate with increased dietary lysine. The BUN values plateaued at .70% dietary lysine. A similar effect took place in experiment 2, as increased dietary lysine resulted in reduced BUN levels, although not significantly. Dietary energy levels in experiment 2 significantly ($P<.05$) affected BUN levels. Increased energy reduced BUN levels from 24.13 to 20.45 mg/100 ml. Energy did not significantly affect BUN levels in experiment 1. The average BUN levels were 12.63 mg/100 ml for the lower energy diets and 12.25 mg/100 ml for the higher energy diets.

In the finishing phase of each experiment, fat also replaced starch in the diet to give diets of 3.42 and 3.72 mcal DE/kg. Lysine was varied from .40 to .65% in .05% increments for each level of dietary energy.

Dietary lysine did not significantly affect rate of gain in the finishing phase of the experiment. However, pigs fed diets containing .50 and .55% lysine did gain 10% faster than those fed diets with .40 and .65% lysine in experiment 1. A smaller difference in gain when feeding lysine was observed in the second experiment as pigs fed diets with .45 and .50% lysine gained 7% faster than pigs fed diets with .40 and .65% lysine. Average daily gain did not differ for finishing pigs due to variation in dietary energy. However, gains were approximately 9% faster for pigs fed the lower energy diets in experiment 2.

Feed consumption in the finishing phase of experiment 1 was significantly affected by variations in both dietary energy and lysine. Consumption of the higher energy diets was decreased ($P<.05$) compared to the lower energy diets. In addition, a significant ($P<.01$) interaction between energy and lysine existed, as feed consumption increased with higher energy diets as dietary lysine increased and decreased as dietary lysine increased for pigs fed the lower energy diets. In the finishing phase of experiment 2, increased energy again significantly reduced feed consumed daily (2.59 vs 2.32 kg/day). Lysine did not significantly affect feed consumption in this experiment.

There were no significant differences in feed efficiency due to variations in lysine or energy levels in the finishing diets. In both experiments, pigs fed the higher energy diets were approximately 4 to 5% more efficient than pigs fed the lower energy diets. Lysine also resulted in a nonsignificant decrease in feed efficiency, as feed/gain ratios decreased from 3.57 for pigs fed diets containing .40% lysine to 3.18 for those fed diets with .65% lysine.

A significant ($P < .05$) linear relationship existed for increasing dietary lysine, as BUN levels decreased in the finishing phase of experiment 2. BUN levels decreased from 13.95 mg/100 ml for pigs fed diets containing .45% lysine to 10.59 for those fed diets with .60% lysine. The BUN levels in the finishing phase of experiment 1 decreased slightly, although not significantly, from 15.32 mg/100 ml for pigs fed diets with .45% lysine to 12.27 mg/100 ml for those fed diets with .65% lysine. Blood urea nitrogen levels did not differ significantly for variations in dietary energy.

The results of this experiment indicate that increasing dietary energy by adding fat will improve feed efficiency and reduce feed consumption in both growing and finishing swine. There was also some indication that increased energy may decrease blood urea nitrogen. Lysine additions reduced the amount of urea nitrogen found in the blood. Increasing energy did not consistently change the requirement for dietary lysine at the levels of energy and lysine studied.

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